1.0 EXECUTIVE SUMMARY

1.1 Introduction

Despite empirical evidence from long-term trend data, for both emission inventories and ambient air quality, that reductions in oxides of nitrogen (NO_x) (simultaneous with volatile organic compound (VOC) reduction) have been beneficial in reducing peak levels of ozone in the SoCAB, and our understanding that photolysis of nitrogen dioxide remains the only significant pathway to ozone formation in the troposphere, predictions obtained through the use of the Urban Airshed Model (UAM) continue to suggest (AQMP Task Force 1994) that further NO_x control will be counterproductive in reducing ozone over most of the SoCAB. The contradiction between UAM predictions and observed air quality trends has led to suggestions that UAM inputs may not represent high ozone episode conditions over a sufficiently wide range of meteorological conditions to adequately model such episodes. For example, much of the regional modeling for the SoCAB has been conducted for a few air pollution episodes, from the Southern California Air Quality Study (SCAQS) conducted in 1987 (SCAQS 1993) or earlier field programs in the SoCAB. In addition, relatively little attention has been given to distinctions between weekend and weekday episodes, yet the fraction of total ozone standard violations which occur on weekends has been increasing over the past decade (Cassmassi 1994).

Clearly, there is a need to better characterize the range of meteorological conditions associated with high air pollution episodes and to assess the influence of air parcel residence time within the SoCAB and weekday/weekend effects on such episodes. Moreover, it is important to carefully analyze air quality trends in the SoCAB over the past decade on a sub-regional basis, and to evaluate correlations between NO_2 and NO_x precursor concentrations and subsequent ozone levels, in order to better evaluate the effects of earlier emission control programs for NO_x and VOC.

1.2 Objectives

The principal overall objectives of this project were to analyze recent air quality trends in the SoCAB on a subregional basis, to examine the relationship between ozone levels and NO_2/NO_x concentrations, and to investigate the influence of air parcel residence time and weekday/weekend effects on conclusions drawn concerning the relative benefits of VOC vs. NO_x control in California's South Coast Air Basin. The specific objectives were:

- To characterize recent (*i.e.*, past decade) air quality trends in the SoCAB on a sub-regional basis, including correlations (or lack thereof) between ozone and NO_2 ambient air concentrations.

- To examine the potential importance of distinguishing meteorologically similar high ozone episodes on the basis of whether the occurrence was on a weekend day or a weekday.

- To characterize days above the California state ozone standard by "residence time" and relate this assessment to the meteorological categories developed by South Coast Air Quality Management District (SCAQMD) meteorologists.

- (Exploratory) To evaluate further the meteorological representativeness of the August 1987 SCAQS episode which has been and will be used for urban airshed modeling in support of development of VOC/NO_x control strategies and future air quality management plans.

- (Exploratory) To explore multiple linear regression relationships between meteorological parameters and ozone.

1.3 Database Development

Comprehensive data for the criteria pollutants NO_2, CO, O_3, and PM-10 and for key meteorological parameters (Table 1-1) were acquired for the years 1986-93.

Table 1-1. Air quality and meteorological databases (1986-93) acquired for the South Coast Air Basin.

Criteria Pollutants	Meteorological Parameters
Ozone	Upper air data
Carbon Monoxide	Resultant wind speed & direction
Nitrogen Dioxide	Temperature
PM-10	Relative Humidity
TSP	Dewpoint
Nitrogen Oxides	FAA data*

* The FAA data (meteorological data from FAA stations in the region of the SoCAB) were available only for 1987-89.

The data set obtained from the ARB was used to generate a new data set containing the daily-maximum hourly-average ozone concentration and the time(s) of occurrence for each day for each station. The completeness of each of these ozone data sets was computed for each station for each smog season in the period 1986-93. For each smog season, the resulting data completeness for each of the stations used in our analyses of daily maximum hourly-average ozone concentrations in the region of the SoCAB, with two exceptions, was 89% or greater.

The ARB data for ambient concentrations of NO_x and NO_2 for the SoCAB from the various air monitoring stations for the eight-year period 1986-93 were subjected to data completeness checks. The morning 5-8 am Pacific Standard Time (PST) (6-9 am Pacific Daylight Time (PDT)) hours generally had greater than 95% data completeness with numerous cases of 98% and 99% completeness.

For the eight smog seasons, various sets of surface and upper-air meteorological data were used to generate a new data base which contained the meteorological data needed to bin

the days according to the Classification and Regression Tree (CART) developed by Horie in 1987. Prior to this application, however, careful examination of the data base was undertaken to identify periods of missing data. To the degree possible, these gaps were filled using computer archives of meteorological data in the UCLA Department of Atmospheric Sciences (for the period 1990-93) and CD-ROM meteorological archives available through the UCLA Library. The resulting completeness of the meteorological data set used in applying the CART scheme was 97% or greater for each of the eight smog seasons in the period 1986-93 (with the exception that for five of the eight years, El Toro wind data were available from the AQMD site but not from the desired FAA site).

1.4 Correlations of Ozone Concentrations With NO_2 and NO_x Ambient Concentrations as a Function of Day of Week and Subregion

Various experimental and modeling studies over the past several decades indicated that transport of ozone-precursor pollutants from the upwind "source" regions of the SoCAB (*e.g.*, West Los Angeles) played a significant and even dominant role in the occurrence of high daily Basin ozone maximum concentrations in the downwind "receptor" regions (*e.g.*, the San Gabriel Valley) of the Basin (National Research Council 1991). However, although the Coastal and Metropolitan subregions have been relatively more densely populated compared to other regions of the Basin, over the past two decades the major growth in the SoCAB has occurred in the middle and eastern portions of the Basin resulting in changing emissions patterns. This raises the possibility that the traditional view of the critical importance of air parcel transport across the SoCAB may no longer be entirely valid. Investigation of the relationships between evening NO_x/NO_2 concentrations and next day ozone maximum concentrations is also relevant to the issues of "residence time" and "carry-over" effects.

To investigate the relationship between daily Basin ozone maxima and morning NO_x emissions on a subregional basis, the correlations between daily hourly-average maximum ozone concentration and average morning 6-9 am Pacific Daylight Time (PDT) NO_2 and NO_x concentrations were examined for the subregions of the Basin shown in Table 1-2. The

correlations were calculated for each day of the week for both 1986-89

Table 1-2. Subregions of the SoCAB employed in this study and air monitoring stations within each subregion for which air quality data were employed.

Subregion	Stations
Coastal	[a, b]Hawthorne [a, b]Long Beach [b]Los Alamitos [a, b]West Los Angeles
Metropolitan	[a, b]Anaheim [b]Burbank [a, b]Central Los Angeles [b]El Toro [a, b]La Habra [b]Lynwood [b]Pico Rivera [b]Reseda [b]Whittier
San Gabriel Valley	[a, b]Azusa [a, b]Glendora [a, b]Pasadena [a]Pomona
Inland	[a, b]Norco [b]Pomona [a, b]Upland
Inland Valley	[b]Banning [a, b]Fontana [b]Hemet [b]Perris [a, b]Riverside [a]San Bernardino
Mountain	Crestline

[a] Stations used in analyses discussed in Chapter 4.
[b] Stations used in analyses discussed in Chapter 6.

(defined in this study as "period I") and for 1990-93 ("period II").

As in many earlier studies, the morning 6-9 am PDT period was chosen because commuter traffic is at a maximum, and these hours typically exhibit low solar insolation and low wind speeds. Under these conditions, average morning ambient air NO_x and NO_2 concentrations can, to a good approximation, be assumed to be representative of morning NO_x and NO_2 emissions, respectively, for the various subregions of the Basin.

1.4.1 Daily Basin O_3 Maximum Concentrations vs. Morning NO_2 and NO_x Concentrations

For all subregions of the Basin and all days of the week, the correlations between morning NO_2 concentration and Basin ozone maximum were better than the correlations between morning NO_x concentration and Basin ozone maximum.

The correlations between the daily Basin ozone maxima and the average morning NO_x and NO_2 concentrations in the "source" region (*i.e.*, the Coastal/Metropolitan subregions) were relatively poor, but were better for period I than for period II. For both periods, correlations were found to be lower on weekdays than on weekend-days.

In the San Gabriel Valley, the correlations for both NO_2 and NO_x with the daily basin ozone maxima were better for period I than for period II for all days of the week, except Monday and Tuesday. The effect that correlations were better for weekend-days than for weekdays, as yet unexplained, was most pronounced for the 1986-89 period for both NO_2 and NO_x. However, good correlations were found for NO_2 for both periods and for all days of the week. In the Inland Valley, NO_2 correlations with the daily Basin ozone maxima were better for weekend-days than for weekdays with the best correlation coefficient found for Sunday.

1.4.2 Daily Subregion O_3 Maximum Concentrations vs. Morning NO_2 and NO_x Concentrations

To further explore the influence of morning NO_x emissions within a given subregion on afternoon peak ozone concentrations within the same subregion, correlation coefficients between these quantities were calculated for all days of the week for both periods. The ozone

concentration maxima within a given subregion were found to be highly correlated with the early morning NO_2 concentrations (and hence emissions) in the same subregion on the same day.

The correlations between average morning Coastal/Metropolitan NO_2 and NO_x concentrations and Coastal/Metropolitan ozone concentration maxima are given in Table 1-3. Reasonably good correlations were found for NO_2 concentrations for all days of the week for both periods.

Table 1-3. Correlation coefficients between daily Coastal/Metropolitan ozone maximum concentration and average morning NO_2 and NO_x concentrations in the Coastal/Metropolitan subregion.

	NO_2		NO_x	
	1986-89	1990-93	1986-89	1990-93
Monday	0.65	0.62	0.32	0.34
Tuesday	0.54	0.67	0.28	0.40
Wednesday	0.52	0.52	0.36	0.31
Thursday	0.57	0.50	0.25	0.21
Friday	0.63	0.49	0.30	0.23
Saturday	0.65	0.61	0.41	0.42
Sunday	0.66	0.64	0.48	0.50

In contrast, the Basin ozone maximum was poorly correlated with the average morning Coastal/Metropolitan NO_2 concentration for all days of the week. This suggests that morning NO_x emissions in the Coastal/Metropolitan subregions may not play as dominant a role in the occurrence of high ozone concentrations in the downwind regions like the San Gabriel Valley and Inland Valley as in the past (prior to the large population growth in these subregions), but contribute significantly to peak ozone concentrations in the Coastal/Metropolitan subregion.

Good correlations between average morning San Gabriel Valley NO_2 and NO_x concentrations and San Gabriel Valley ozone concentration maxima were found for both periods and for all days of the week for NO_2; correlations were highest for Friday through Sunday for period I. The correlation coefficients for NO_2 ranged from 0.63 to 0.75 for period I, and from 0.56 to 0.70 for period II.

The correlations between average morning Inland Valley NO_2 and NO_x concentrations and Inland Valley ozone maxima are given in Table 1-4. Good correlations were found for both periods and for all days of the week for NO_2; correlations were somewhat better for weekend days and Friday than for the other weekdays.

Table 1-4. Correlation coefficients between daily Inland Valley ozone maximum concentration and average morning NO_2 and NO_x concentrations in the Inland Valley subregion.

	NO_2 1986-89	NO_2 1990-93	NO_x 1986-89	NO_x 1990-93
Monday	0.57	0.62	0.26	0.38
Tuesday	0.57	0.66	0.22	0.42
Wednesday	0.61	0.54	0.20	0.25
Thursday	0.63	0.62	0.22	0.29
Friday	0.72	0.66	0.42	0.36
Saturday	0.69	0.67	0.47	0.44
Sunday	0.72	0.67	0.52	0.54

1.4.3 Daily O_3 Maximum vs. Previous Evening's NO_2 and NO_x Concentrations

Significant NO_x emissions occur in the SoCAB during evening hours from commuter traffic; in the western portion of the Basin stationary sources (*e.g.*, electric utilities and oil refineries) can also produce significant NO_x emissions during the evening and night-time hours. The degree to which carryover of NO_x emissions might influence early-morning ambient NO_2 and NO_x concentrations is dependent upon meteorological factors which control

the dispersion and transport of pollutants. Fujita et al. (1992) found that carryover of emissions from the previous day may affect early morning ambient concentrations more during Fall months than during the summer months investigated in the present study.

To investigate whether transport of evening NO_x emissions from the Coastal/Metropolitan subregions influenced the peak ozone concentration in the Basin on the following day, the evening (6-9 PDT) Coastal/Metropolitan average NO_2 and NO_x concentrations were correlated with the following day Basin ozone maximum for Tuesday/Wednesday and for Friday/Saturday. Tuesday evening/Wednesday was assumed to be representative of typical weekdays, while Friday evening/Saturday was assumed to be representative of weekend-days.

The evening NO_x emissions within a given subregion might also contribute to the next day's early morning NO_x concentration in the same subregion. To investigate this possibility, correlations between the daily subregion ozone maxima and the previous evening's average NO_x and NO_2 concentrations in that subregion were also investigated for Tuesday/Wednesday and Friday/Saturday.

The correlations between the Coastal/Metropolitan average Tuesday evening NO_x concentration and the Wednesday Basin ozone maximum and the Wednesday Coastal/Metropolitan ozone maximum were both quite small, suggesting little relationship between weekday evening NO_x and following day maximum ozone. The correlations between Friday evening average Coastal/Metropolitan NO_x concentration and Saturday Basin ozone maximum and Coastal/Metropolitan ozone maximum were also poor. These results suggest that carryover of evening NO_x emissions from the Coastal/Metropolitan subregion may not have significantly influenced the daily ozone maximum either in the Coastal/Metropolitan subregion or in the Basin as a whole for the May-October months during the eight-year period investigated in the present study.

The correlations between the daily Basin ozone maximum, the San Gabriel Valley ozone maximum, and the previous evening average San Gabriel Valley NO_x or NO_2 concentrations were also poor.

Assuming the average evening (5-8 pm PST) ambient NO_x concentration was

representative of the evening NO_x emissions from on-road mobile sources, these results suggest carryover of evening NO_x emissions from mobile sources in the San Gabriel Valley may not have influenced the daily ozone maximum in the Basin (and hence typically the San Gabriel Valley ozone maximum) to a significant extent during the period of this study.

1.5 Examination of Air Parcel Residence Time and Other Meteorological Parameters

Various previous observational and modeling studies have indicated there is a relationship between the ambient meteorological conditions and the occurrence of high concentrations of ozone in the SoCAB. In order to facilitate identification of those meteorological factors associated with the occurrence of high ozone values, we took the approach of examining the difference in meteorological conditions between those days on which a very high ozone value was reported somewhere in the SoCAB and those days on which the ozone value was simply average. A significant limitation of this analysis was the lack of adequate upper air meteorological data. More robust examination of the important issue of air parcel residence time would require the implementation of a mesoscale upper air meteorological network in the SoCAB.

In undertaking this analysis, we first ranked each smog season day for the years 1990-93 on the basis of the highest hourly-average ozone values reported in the SoCAB. It quickly became apparent, however, that virtually all of the highest ozone values occurred at one of the following four locations: Riverside, Crestline, Fontana, and Glendora. Since our objective was a description of the meteorological conditions associated with the typical occurrence of very high ozone values within the SoCAB, we limited our analyses to those days on which the peak ozone report came from one of these four sites.

The middle day in the ranked distribution had a peak ozone value of 15 pphm; there were 28 days during the 4-year period for which this was the Basin-maximum ozone value reported. In order to have comparably-sized groups of days for comparison, the high ozone days were defined as the first 28 days in the distribution; maximum values for these days ranged from 33 pphm to 25 pphm.

1.5.1 Surface Meteorological Conditions: High Ozone Days vs. Middle Ozone Days

Vector average 1-hour resultant winds were calculated from 0700 PDT to 1800 PDT for each station in the SoCAB for the set of high ozone days and for the set of middle ozone days. For both the high and middle ozone days, 1-hour resultant winds were generally 1 knot or less prior to 0900 PDT. Then weak ventilation of the Basin appeared for both sets of days, with general surface flow from coastal regions towards the interior. As the time of day progressed into the early afternoon, the strength of the surface flow towards the interior increased, but little difference appeared between the high ozone days and the middle ozone days. Wind speeds for both groups of days decreased in the late afternoon. Implications of these results include the following: westerly-southwesterly ventilation begins throughout the SoCAB at approximately the same time, rather than showing the eastward propagation of a discrete sea breeze front; significant surface transport between coastal areas and the far inland portions of the SoCAB is unlikely to occur in a single day; and variation in surface transport does not significantly influence the peak SoCAB ozone level. However, only surface wind data were available to us for the SoCAB and the actual transport will be determined by the three dimensional wind field.

Further understanding of the roles of transport and residence time was obtained from examination of the foregoing resultant wind analyses in conjunction with an analysis of the average initial hour of occurrence of the daily ozone maximum at each SoCAB station for the 28 high ozone days. This analysis revealed little variation in the average time of initial occurrence of the peak ozone value throughout a large part of the western SoCAB. Progressively later times of first occurrence of peak ozone at stations farther to the east suggests that at these locations transport from the west is important, but details of the analysis indicate the transport pattern is complex, with transport perhaps significant only within a particular subregion and between adjacent subregions.

A similar analysis for the 28 middle ozone days also suggests transport is perhaps only of significance within limited sub-domains of the SoCAB and not across the entire horizontal extent of the Basin. However, details of both this analysis and the aforementioned resultant wind analysis suggest surface transport is somewhat more from the west on high ozone days

and somewhat more from the south on middle ozone days.

Additional examination of the roles of transport and residence time was enabled by examining the SoCAB resultant surface winds as a function of time of day along with the average initial hour of occurrence of the daily ozone maximum at each SoCAB station for just the 19 out of the 28 high ozone days that the ozone maximum occurred at Glendora, and for just the 6 out of the 28 high ozone days that the ozone maximum occurred at Crestline. Results of the former analyses suggest the precursor pollutants responsible for the highest hourly ozone occurrences in Glendora might originate from only a relatively short distance to the west, while results of the latter suggest two possible routes of transport to Crestline on the worst ozone days at that location: one from the San Bernardino area to the south, and the other along the southern base of the San Gabriel Mountains to the west-southwest (but not from as far west as the Coastal/Metropolitan subregions).

These analyses were then extended through determination of backward surface trajectories from Glendora (for the Glendora high ozone days) and from Crestline (for the Crestline high ozone days). These were found using the corresponding resultant surface wind analyses for each of these two groups of days, with parcels "started" at Glendora and Crestline at the respective mean initial times of occurrence of the daily maximum ozone value. Results are consistent with the findings noted above.

A limitation of the foregoing resultant wind analyses is that the resultant wind speeds and directions do not necessarily well-represent the individual reports they comprise. To directly examine the variation in wind speeds and directions among selected groups of wind observations, wind roses were constructed for the resultant 0800-0900 PDT wind and the resultant 1400-1500 PDT wind for both West Los Angeles and Glendora and for both the 28 high ozone days and the 28 middle ozone days. At the earlier time (0800-0900 PDT) on the high ozone days, the winds at West Los Angeles were predominantly very light and out of the south, while the predominant wind direction at Glendora was southwesterly but with a typical wind speed of less than 0.5 mph. Quite similar results were found for the middle ozone days, except the wind direction at West Los Angeles tended to be less predominantly southerly and instead more southwesterly (primarily) or easterly (secondarily). Striking similarity between

middle and high ozone days was also apparent in the afternoon (1400-1500 PDT) wind roses. At both locations and for both the high ozone days and the middle ozone days, the flow is predominantly from the southwest. In summary, then, these wind rose analyses also imply that variation in surface transport in itself is not a dominant factor in determining the daily SoCAB peak ozone level for the period 1990-93.

In contrast to the apparent similarity in low-level wind flow between the high and middle ozone days, the average maximum surface (air) temperatures were significantly different between the two groups of days. At all of the stations in the SoCAB with temperature data (with the exception of Hawthorne), the decrease in average maximum surface temperature was 9 °F or greater between the high ozone and middle ozone days. The implication is thus that surface heating is a significant factor in determining the daily SoCAB peak ozone level for the period 1990-93.

1.5.2 850 mb Meteorological Conditions: High Ozone Days vs. Middle Ozone Days

Data at the 850 mb pressure level (approximately 5000 feet above sea level) are provided by balloon-borne radiosondes, routinely launched at 1200 GMT (0500 PDT) and 0000 GMT (1700 PDT) from rather widely-spaced stations. The two closest radiosonde sites to the SoCAB that have daily reports throughout the period are San Diego to the south and Vandenberg Air Force Base (AFB) to the northwest. Temperature and wind data from these two sites were utilized.

An approximate 850 mb temperature for the SoCAB was defined by averaging the values simultaneously reported by the San Diego and Vandenberg AFB sites. At both 0500 PDT and 1700 PDT, the average SoCAB 850 mb temperature for the 28 high ozone days was significantly greater than that for the 28 middle ozone days. At the latter time, none of the 850 mb temperatures for high ozone days were lower than the highest 850 mb temperature for a middle ozone day.

Vector-average 850 mb winds were found separately for Vandenberg AFB and San Diego at both 0500 PDT and 1700 PDT for both middle and high ozone days. In general, differences between the two sets of days were fairly small. It did appear, though, that the 850

mb winds were somewhat stronger and more northerly on high ozone days than on middle ozone days.

Further examination of the 850 mb winds was enabled by the construction of wind roses for the 1700 PDT 850 mb radiosonde wind observations at Vandenberg AFB and San Diego. At both locations and for both middle and high ozone days, a variety of wind directions were evident. Winds did tend to be somewhat more northerly at Vandenberg AFB and northwesterly at San Diego on high ozone days than on middle ozone days.

1.5.3 Pattern Number: High Ozone Days vs. Middle Ozone Days

Five different synoptic patterns, described by the contour signature at the 500 mb level, were defined by Cassmassi (1987) for ozone prediction stratification. Among the data received from the SCAQMD for the present study was a number indicating the classification of each day according to this set of synoptic patterns.

The pattern number distribution for the 28 high ozone days was compared with that for the 28 middle ozone days. All but three of the high ozone days were associated with pattern number 4 (a high pressure ridge over California, with 500 mb heights approaching or exceeding 5880 m throughout the study area), while the majority of the middle ozone days were associated with pattern number 3 (zonal flow or a "building" high pressure ridge, characterized by a moderate pressure gradient and 500 mb heights somewhat higher to the southwest). The implication is that the highest ozone values occurred in association with very high 500 mb heights and thus warm troposphere-mean temperatures, while lower ozone days tended to be associated with lower 500 mb heights and thus cooler troposphere-mean temperatures, and stronger flow aloft. However, since a not insignificant number of middle ozone days had the same pattern number as did most of the high ozone days, the pattern number as defined by Cassmassi (1987) cannot fully account for the difference in characteristic synoptic-scale meteorological conditions between high and middle ozone days.

1.5.4 Application of the CART Scheme

Horie (1987) developed a Classification and Regression Tree (CART) scheme which was used to separate each day of the 3-year period 1983-85 into ten different categories (nodes) based on meteorological conditions. In the present study, this CART scheme was used to bin the smog season days from the 8-year period 1986-93 into the 10 nodes of the tree in 4 different ways. First, the smog season days for each of the years 1986-93 were individually binned using the CART scheme. Then, all of the smog season days for 1986-89 were treated as one group for binning and those for 1990-93 were treated as a second group. Next, the 28 high ozone days and the 28 middle ozone days for the smog seasons of 1990-93 were binned according to their associated node in the CART scheme. Finally, the weekdays (here represented by Tuesday and Wednesday) and the weekend days (Saturday and Sunday) were separately binned for the two four-year periods 1986-89 and 1990-93.

When the smog season days for each of the years 1986-93 were individually binned using the CART scheme, it was found for each of the 8 years that the highest Basin-maximum ozone concentration was associated with node 10. This node is characterized by very warm temperatures at 850 mb and 900 mb (and thus probably very high inversion temperatures) and morning winds at El Toro ranging from west-southwesterly to northwesterly. However, Basin-maximum ozone values associated with this node were significantly less in the latter four years than in the earlier four years, and were lower for all years of our study than the 1983-85 average for this node of 28.9 pphm reported by Horie. Thus, under similar meteorological conditions conducive to ozone formation, peak ozone values appear to have decreased and have thus apparently decreased for other than meteorological reasons.

When all of the smog season days for 1986-89 were binned together by node of the CART scheme and then compared with the smog season days for 1990-93, it was found the Basin-maximum ozone value for each of the 8 CART nodes into which the days were distributed was lower for the latter group of years than for the earlier 4-year period. The implication is thus that regardless of the meteorological conditions, generally lower peak ozone values were observed in the latter four years than in the earlier four years. However, the magnitudes of the reductions were comparatively small, and thus attribution to other than

meteorological influences, while likely, is not definitive.

Finally the 28 high ozone days and the 28 middle ozone days for the smog seasons of 1990-93 were binned according to their associated nodes in the CART tree. While sixteen of the high ozone days were classified as node 10 and four as node 9, none of the middle ozone days were associated with either of these nodes. Nodes 9 and 10 are distinguished by having the warmest temperatures at both 850 and 900 mb.

1.6 Characterization of Weekday/Weekend Effects

The ozone database (1986-93) was analyzed for differences in daily ozone maxima on weekdays vs. weekend days for the air pollution season (May-October). As simple averages of daily ozone maxima were not found to be a useful metric for distinguishing weekday/weekend differences, other indices of weekday vs. weekend differences were investigated.

1.6.1 Daily Maximum Ozone Distributions for Weekdays vs. Weekend Days

For the 1986-93 period, ozone daily maximum data for stations at Central Los Angeles (L.A.), Azusa, and Riverside were analyzed for weekday/weekend differences in the distribution of ozone concentrations. Many of the higher daily maximum ozone concentrations occurred on weekend days while the lower daily maximum concentrations were more frequent on the weekdays. Enhancement of this difference appeared to occur in the later years of the period studied.

1.6.2 Ozone First Stage Alerts and Cumulative Hourly Exceedance for Weekdays vs. Weekend Days

As defined by the SCAQMD, a first stage alert for ozone is declared if the hourly-average ozone concentration equals or exceeds 20 pphm at any station in the SoCAB. A computer program was developed to compare the number of ozone first stage alerts on weekdays and weekend days for the air monitoring stations at Central LA, Azusa, and Riverside.

For the entire eight-year period 1986-93 a greater number of ozone first stage alerts occurred on Saturday/Sunday than on weekdays for the Azusa station but not for the Riverside station. The number of ozone first stage alerts for each day of the week for each year between 1986 and 1993 for the same two stations was also plotted and a general decline in the number of ozone first stage alerts was observed for all days of the week over the eight-year period. The Azusa station and Central L.A. station appear to have experienced greater declines over the eight-year period in the number of ozone first stage alerts on weekend days than did the Riverside station.

The cumulative hourly ozone exceedance above the federal standard of 12 pphm was also computed for each day of the air pollution season for each of the eight years of interest for the Central L.A., Azusa and Riverside stations. In general, the cumulative ozone exceedance decreased over the eight-year period (1986-93) for all days of the week at all three stations. These data also indicated that although in general ozone exceedances for Central LA and Azusa were higher on weekend days as compared to weekdays, this was not necessarily true for Riverside, consistent with the finding for first stage alerts.

1.6.3 Weekday/Weekend Analyses Using the CART Scheme

The CART scheme developed by Horie (1987) was used to bin the smog season days into the 10 different nodes of the tree. Weekdays (here represented by Tuesday and Wednesday) and weekend days (Saturday and Sunday) were separately binned for the two four-year periods 1986-89 and 1990-93.

A general increase was observed in mean (daily-maximum hourly-average) ozone value with node number in Horie's CART scheme. On average, the worst ozone days were defined by node 10, characterizing 6%-8% of the smog season days. However, the standard deviations were sufficiently large that many of the CART nodes cannot be considered as statistically distinct from each other.

1.6.4 Examination of Ten Days with Highest Hourly-Average Ozone Concentrations: 1986-89 vs. 1990-93

To further investigate the trends noted from application of the CART scheme, we examined the means of the ten highest daily hourly-average ozone concentrations for each of the four-year periods for each of the stations for which data were available. In other words, we examined the trends as seen on the worst ozone days at each station. As shown in Figure 1-1, we found the most significant ozone decreases between the two four-year periods occurred in the western and middle portions of the SoCAB for the worst ozone days, corresponding generally to the area of maximum percentage decrease in early morning NO_x ambient concentrations for these same highest ozone days, as shown in Figure 1-2.

For the period 1986-89, the mean of the ten highest daily ozone values on weekend days was higher than the mean for those on weekdays (here taken to be Tuesdays and Wednesdays) for all Coastal subregion stations considered, and for most (7 out of 9) of the Metropolitan subregion stations. However, the reverse was true for all of the Inland Valley subregion stations (as well as the one Mountain station), and for 2 out of 3 stations in both the San Gabriel Valley subregion and the Inland subregion.

For the period 1990-93, the mean of the peak concentrations on the weekend days was higher than that on the weekdays for all stations in all subregions, with the exception of two stations in the far eastern end of the SoCAB (Crestline, and Banning) where the weekday mean was only very slightly higher than that for weekend days.

1.6.5 Weekday/Weekend Differences in Ambient NO_2, NO_x, and NO_2/NO_x

WD vs. Saturday: Taking the means of NO_2, NO_x and the NO_2/NO_x ratio for the combined Coastal and Metropolitan subregions for the period 1986-89, Saturdays had 18% lower NO_2 levels, 32% lower NO_x levels, and 17% higher NO_2/NO_x ratios than the weekday average. Similar results were found for the period 1990-93.

WD vs. Sunday: Again, combining the data for the Coastal and Metropolitan subregions, for the period 1986-89, Sunday had 26% lower NO_2 levels, 43% lower NO_x levels, and 28% higher NO_2/NO_x ratios than the weekday average. Corresponding values fig

1-1

fig1-2

for the period 1990-93 were 27%, 52%, and 36%, respectively.

In general, these early morning ambient air concentration data suggest that only a modest decrease in emissions of NO_x occurred in the Coastal/Metropolitan subregions between the two four-year periods under study here. Specifically, combining the NO_x data for the two subregions, weekdays (as represented by Wednesday/Thursday) and Saturday experienced only a 3% decrease in NO_x concentrations between 1986-89 and 1990-93, while Sunday and Monday experienced an 18% decrease in NO_x concentrations for the combined subregions. The change in NO_2 concentrations varied less by day of the week, with a decrease of 14% for Weekdays, 12% for Saturday, 16% for Sunday, and 18% for Monday.

1.7 Principal Findings

The principal findings of this study were as follows.

- Peak ozone concentrations in the SoCAB were generally much better correlated with NO_2 concentrations than with NO_x concentrations.

- In general, the highest correlations between morning NO_2 and peak ozone concentrations occurred on weekend days and Fridays.

- High intra-subregion, same day correlations between morning NO_2 and peak ozone were observed throughout the Basin, particularly in the San Gabriel Valley and Inland Valley subregions.

- Correlations were weak between evening NO_2 or NO_x and the next day's Basin peak ozone during the smog season months for the 1986-93 period investigated here.

- Significant differences in these correlations were observed between the 1986-89 and 1990-93 periods, suggesting continuing changes in the spatial distribution of emissions in the Basin over this period and/or the influence of different multi-year meteorological patterns.

- Little difference in surface wind field was evident between high ozone days and average ozone days.

- Differences in 850 mb winds between high ozone days and average ozone days were relatively small.

- Maximum surface air temperatures, and both early morning and late afternoon 850 mb temperatures, were significantly higher on high ozone days than on average ozone days.

- Application of the CART scheme to each of the 8 years of the study showed that the highest Basin-maximum ozone concentration was associated with node 10, which is characterized by very warm temperatures at 850 mb and 900 mb, as well as morning onshore flow at El Toro.

- Basin-maximum ozone values associated with CART node 10 were significantly lower in the latter four years than in the first four years covered by this study, and were lower for all years of the present study than the 1983-85 average for this node of 28.9 reported by Horie. Lower Basin-maximum ozone values were also found for the other seven CART nodes for the second four years.

- As well documented earlier by ARB, SCAQMD and others, substantial reductions in peak ozone concentrations occurred in all regions of the Basin and across all days of the week between 1986-89 and 1990-93, although the percentage reductions were greatest in the western and middle portions of the Basin. On average there were greater reductions on weekdays than on weekends and hence the differences in WD vs. WE daily ozone maxima increased in the 1990-93 period over the 1986-89 period.

- An examination of the worst ozone days, specifically the ten highest daily hourly-average ozone concentrations for each of the two four-year periods for each station for which data were available, showed the most pronounced percentage decrease in these highest ozone concentrations occurred in the western and middle portions of the Basin, corresponding generally to the area of maximum percentage decrease in early morning NO_x ambient concentrations for these same highest ozone days.

- The distribution by day-of-the-week of the ten highest ozone concentrations in the Basin for each year for each station in the period 1986-93, showed these episodes occurred significantly more often on Saturdays than on Sundays through Wednesdays.

- Similarly, for the period 1990-93, the means of the peak ozone concentrations for the top ten days were higher on weekend days than on weekdays for all stations in all subregions (with the exception of Crestline and Banning).

- On average, early morning ambient concentrations of NO_2 and NO_x during the eight year period studied were lower by approximately 20-25% and 30-50%, respectively on weekend days than on typical weekdays in the Coastal/Metropolitan subregions.

- Significantly more comprehensive upper air data are required to better characterize air parcel transport and carry-over effects.